AIR POLLUTION IMPACTS AND REVENUE IMPLICATIONS OF LNG TAXATION

FINAL REPORT

May 17, 1996

Submitted to:
U.S. Environmental Protection Agency
Washington, D.C.

Engine, Fuel, and Emissions Engineering, Incorporated

9812 Old Winery Place, Suite 22
Sacramento, CA 95827-1732 USA

ph. (916) 368-4770
fax (916) 362-2579

Air Pollution Impacts and Revenue Implications of LNG Tax Policy

Final Report
EPA Contract No. 68-W2-0018
Work Assignment No. 7-07

Report to
U.S. Environmental Protection Agency
401 M St. S.W.
Washington, D.C. 20460

May 17, 1996

submitted by
Christopher S. Weaver, P.E.
Lit-Mian Chan
Engine, Fuel, and Emissions Engineering, Inc.
9812 Old Winery Place, Suite 22
Sacramento, CA 95827
(916) 368-4770

CONTENTS

LIST OF TABLES

1. INTRODUCTION

Natural gas is among the most promising "clean" alternative fuels for vehicles in the U.S., especially for heavy-duty vehicles that now use diesel engines. Heavy-duty natural gas engines are now commercially available in limited numbers, and some engine models have been certified with emission levels more than 80% less than the stringent 1998 emission standards for heavy-duty diesel engines.

Natural gas is composed mainly of methane, which is a gas at normal temperatures and pressures. In order to achieve reasonable vehicle range, the storage density of natural gas for vehicular use must be increased. This is done either by compressing it to pressures of 3000 to 3600 PSI (compressed natural gas or CNG), or by liquefaction at cryogenic temperatures (LNG). Although LNG is more expensive to produce than CNG, the energy density of LNG (BTU per unit of volume) is about three times that of CNG, and only 40% less than that of diesel fuel. LNG tanks are also much lighter than CNG tanks for the same energy content, and only slightly heavier than diesel. These characteristics make LNG a more attractive choice than CNG for applications that require large quantities of fuel to achieve sufficient range, or for which the weight penalty of CNG cylinders would require payload to be reduced in order to remain within vehicle weight limits. These applications include long-haul trucks, garbage trucks, dump trucks, and transit buses.

In the Omnibus Budget Reconciliation Act of 1993, the U.S. Congress raised existing taxes on diesel and gasoline for road use, and adopted a tax of 48.54 cents per thousand standard cubic feet (MCF) on CNG used by road vehicles. Based on the energy content of pure methane, this tax rate is equivalent to 50.3 cents per million BTU lower heating value, or 6.6 cents per diesel equivalent gallon[1]. Congress did not specify the rate of tax to be applied to LNG in this legislation. If the same tax rate were applied to LNG as to CNG, however, it would be equivalent to 3.82 cents per LNG gallon. However, regulations issued by the Internal Revenue Service on August 7, 1995 defined LNG as a "special motor fuel", subject to a tax rate of 18.4 cents per LNG gallon. This is the same tax rate per gallon as gasoline, and somewhat less than the 24.4 cent per gallon tax on diesel. Because LNG contains less energy per gallon, however, the rate of tax per

[1] A gallon of diesel fuel contains about 131,000 BTU of energy, based on the lower heating value, while a standard cubic foot of methane contains 965 BTU, and a gallon of saturated LNG at atmospheric pressure contains 75,900 BTU. A diesel equivalent gallon is that amount of natural gas having the same energy as one gallon of diesel, and is equal to 1.73 gallons of LNG, or 136 SCF of gaseous methane.

unit of energy in the fuel is much higher than for gasoline or diesel, amounting to $2.42 per million BTU, and 31.8 cents per diesel equivalent gallon.

The IRS's decision greatly reduced the economic attractiveness of LNG as an alternative to diesel fuel, and thus reduced the potential market penetration by LNG-fueled heavy-duty trucks (fuel for transit buses is tax-exempt, and therefore unaffected by the decision). This report examines the impacts of that decision on the status of the LNG market for transportation fuel, the resulting environmental impacts, and the tax revenue implications of removing the differential taxation between LNG and CNG.

2. LNG MARKET IMPACTS

The IRS's decision on LNG taxation has greatly reduced the interest of private-sector trucking companies in LNG usage. To assess this impact, we reviewed market penetration estimates for LNG trucks developed in a study by Zeus Development Corporation for the Gas Research Institute (GRI). In addition, we contacted several of the commercial organizations involved in the area by telephone to ask about the decision's impact on their plans. Finally, we developed our own economic model to assess the impact of LNG taxation and other factors on the return on investment offered by LNG vehicles.

2.1 Zeus Development Corporation Projections

EF&EE reviewed a report on potential markets and infrastructure requirements for LNG vehicles, prepared by Zeus Development Corporation for the Gas Research Institute (Nimocks, 1995). This report projected potential market penetration under several scenarios. These included one scenario in which the IRS tax decision remains unchanged, one in which the tax on LNG is reduced to the same level as the tax on CNG, and one in which the tax is reduced and vehicle owners are able to take advantage of mobile-source emission reduction credits (MERCs) with a value of $2,000 per ton of NOx eliminated. A fourth scenario also included the lower tax rate, along with state tax credits for the incremental investment in vehicles and fueling systems - a proposal that recently failed passage in the California legislature.

Table 1: Zeus Development Corporation projections of heavy-duty LNG vehicle populations.

	Urban Buses	Line-Haul Trucks	Urban Trucks
Scenario 1: Current LNG Tax Structure			
1995	450	37	29
2000	0	0	0
2005	0	0	0
2010	0	0	0
Scenario 2: LNG Tax Reduced to CNG Level			
1995	450	37	29
2000	1,100	1,000	1,000
2005	1,600	2,750	5,250
2010	2,100	5,250	10,250
Scenario 3: LNG Tax Reduced to CNG Level + MERCs			
1995	450	37	29
2000	2,250	1,750	2,200
2005	3,000	5,250	8,500
2010	3,500	7,250	11,000

Table 1 shows the LNG market projections for the first three scenarios in the Zeus report. The author divided the potential market for LNG into three categories: fleets using LNG for R&D demonstrations, fleets (nearly all public transit fleets) using LNG for compliance with government clean fuel mandates; and fleets using LNG for economic benefits. Market penetration in this latter category, which has by far the largest potential, is projected to be zero among on-highway vehicles if the present LNG tax structure remains in place. According to Zeus' analysis, the present tax eliminates any potential for economic advantages from LNG use. As further described in Section 2.3, EF&EE's economic analysis shows the same result. In addition, Zeus projected that the collapse of this potential market, with the resulting lack of investment in LNG technology and perceived lack of government support for LNG would eliminate LNG use in the other two categories as well. On the other hand, reducing the tax rate on LNG to the same level as that on CNG would restore the economic viability of the LNG option, and result in modest levels of market penetration by the second half of the next decade.

In our opinion, the Zeus report's projections of LNG market potential among urban and line-haul trucks are reasonable, and we have adopted them for our analysis as well. The projections of market penetration among transit buses may be overly pessimistic, however, as fuel for these buses is tax-exempt, and their economics are thus not directly affected by the IRS decision. We are also aware of ongoing interest and some potential fleet purchases of LNG transit buses, despite the setback dealt to the LNG market as a whole by the IRS decision. Because transit bus economics are not directly affected by the tax, and the impacts are thus difficult to predict, we have decided to exclude buses from our evaluation of the tax impact.

2.2 Results of Industry Contacts

To obtain further information on the impacts of the IRS tax decision on the market for LNG in heavy-duty vehicles, EF&EE contacted several organizations that have been prominent in LNG vehicle commercialization efforts. These included Zeus Development Corporation. In our conversation, Mr. Nimocks indicated that he still considers the conclusions and projections of the 1995 Zeus report to be valid. He also indicated that interest in LNG among commercial truck operators has essentially collapsed as a result of the IRS decision, and that the only potential markets that are now showing much activity are transit and non-road equipment markets that are exempt from the tax.

EF&EE also contacted Ken Kelley of Jack B. Kelley, Inc., a line-haul carrier that has been among the pioneers in the use of LNG. Mr. Kelley indicated that, at the time the IRS decision was announced, his company had 11 LNG tractors on order, and had ordered $3 million worth of equipment for LNG fueling stations. The tax decision caused his company to cancel its plans for aggressive development of LNG. Although the company has taken delivery of the eleven tractors, and is presently operating them, it has no plans to purchase any more. Most of the LNG fueling system equipment is being diverted to other uses, or sold.

EF&EE also spoke by telephone with Nick Kendle of LNG Energy, Inc., a western distributor of LNG for vehicular use. He also confirmed that the IRS tax decision had essentially eliminated

Table 2: Model of LNG truck economics.

	LNG Tax at 18.4 Cents/Gallon				LNG Tax Equal CNG Tax Rate			
	Line Haul Truck		Urban Truck		Line Haul Truck		Urban Truck	
	Diesel	LNG	Diesel	LNG	Diesel	LNG	Diesel	LNG
Fuel Consumption								
Energy/mile (BTU)	26,200	27,510	32,750	34,388	26,200	27,510	32,750	34,388
Energy/gallon (BTU)	131,000	75,900	131,000	75,900	131,000	75,900	131,000	75,900
Fuel Cons. (MPG)	5.00	2.76	4.00	2.21	5.00	2.76	4.00	2.21
Annual Miles	120,000	120,000	40,000	40,000	120,000	120,000	40,000	40,000
Ann. Fuel. Cons. (gal)	24,000	43,494	10,000	18,123	24,000	43,494	10,000	18,123
Fuel Costs								
Fuel Price								
Base price	0.850	0.450	0.850	0.450	0.850	0.450	0.850	0.450
Federal tax	0.244	0.184	0.244	0.184	0.244	0.038	0.244	0.038
State tax	0.200	0.100	0.200	0.100	0.200	0.100	0.200	0.100
Total	$1.294	$0.734	$1.294	$0.734	$1.294	$0.588	$1.294	$0.588
Annual Fuel Cost	31,056	31,925	12,940	13,302	31,056	25,583	12,940	10,660
Federal Tax	5,856	8,003	2,440	3,335	5,856	1,661	2,440	692
Annual Fuel Cost Saving		(869)		(362)		5,473		2,280
Capital Costs and Net Present Value								
Incremental Capital Cost	0	15,000	0	10,000	0	15,000	0	10,000
Less Tax Deduction Value		5,250		3,500		5,250		3,500
Retention Time (years)		5		10		5		10
Less Discounted Residual Value		2,483		823		2,483		823
Discount Rate		15%		15%		15%		15%
NPV of Fuel Savings		(1,893)		(1,181)		11,925		7,439
NPV of Investment w/o MERC		(11,643)		(7,681)		2,175		939
NPV of Investment w MERC		(4,573)		(2,832)		9,244		5,787
Pollutant Emissions and MERC Value								
NOx emissions (g/mi)	9.70	6.26	13.33	8.60	9.70	6.26	13.33	8.60
NOx emissions (tons/yr)	1.28	0.83	0.59	0.38	1.28	0.83	0.59	0.38
NOx MERC value @ $3,000/ton		1,365		625		1,365		625
PM emissions (g/mi)	0.626	0.063	0.860	0.086	0.626	0.063	0.860	0.086
PM emissions (tons/yr)	0.083	0.008	0.038	0.004	0.083	0.008	0.038	0.004
PM MERC value @ $10,000/ton		744		341		744		341

any interest in LNG usage by commercial truck operators, many of whom had previously been interested.

2.3 Economic Model of LNG Utilization

To further explore the impacts of the IRS tax decision on the economics of LNG use in trucking, EF&EE developed a simple economic model. Two types of trucks are considered in the model: a line-haul tractor similar to those operated by Jack B. Kelley, Inc. and other trucking firms, and an "urban truck", such as a garbage truck. These are considered to be two of the best private-sector markets for LNG. As mentioned earlier, transit buses would not be affected directly by the IRS ruling, and we have therefore excluded them from this analysis.

Table 2 shows the assumptions and results of the economic model. The base diesel trucks are assumed to travel 120,000 and 40,000 miles per year, with fuel economies of 5.0 and 4.0 MPG, respectively. LNG fuel consumption is calculated by assuming 5% higher energy consumption per mile than for diesel. The energy-efficiency with LNG is less than with diesel because LNG is used in Otto-cycle engines, which suffer from reduced efficiency at light loads due to throttling losses.

The LNG and diesel fuel prices shown in the model include the estimated base (ex tax) prices per gallon for LNG and diesel fuel (including wholesale costs plus the retailer's profit), plus state and federal taxes. State taxes on motor fuels are summarized in Appendix A. As this appendix shows, state taxes on diesel fuel range from 18 to 21 cents per gallon in the majority of states. Some states do not tax LNG at all, some tax it at a reduced rate, and some tax it at the same rate per gallon as for gasoline. Overall, taking into account that truckers will tend to buy fuel and establish depots in those states offering more attractive tax rates, we estimated the average state taxes on diesel and LNG as 20 and 10 cents per gallon, respectively.

The incremental capital costs of an LNG truck were estimated at $15,000 and $10,000 over the costs of the corresponding diesel for line-haul and urban trucks, respectively. This is much less than the present price premium, which can range up to $50,000, but is considered representative of the long-term situation. In the long term, LNG engines should cost no more than diesel engines, but the expensive cryogenic tanks required for LNG will still mean that the vehicle as a whole costs somewhat more.

The capital cost of the LNG equipment would be reduced somewhat by the fact that it can be deducted immediately from federal taxes, rather than being amortized over the life of the equipment. These tax benefits are offset to some degree by the fact that fuel costs are a deductible operating expense, and therefore not subject to income tax. Both the value of the tax deduction and the discounted present value of the fuel costs were calculated assuming the owner is in the 35% federal corporate tax bracket, and requires an after-tax return on capital of 15%. The net present value of the incremental investment in an LNG truck is shown for two cases: one reflecting the status quo, with a tax rate of 18.4 cents per gallon on LNG, and the other assuming that LNG was taxed at the same rate as CNG. As Table 2 shows, the calculation reflecting the status quo shows negative savings on fuel cost, resulting in a large negative number for the net present value of the investment. Even incorporating the value of possible MERCs (valued rather optimistically at $3,000 per ton of NOx and $10,000 per ton of PM2.5) would not make LNG a good investment. The assumptions used in the MERC calculation are discussed in the next chapter. With the Federal tax on LNG set at 3.82 cents per gallon, on the other hand, the incremental investment in LNG technology displays a small positive NPV, even without considering the possible value of MERCs. Thus, the difference in taxation has a critical effect on the financial viability of the investment.

3. ENVIRONMENTAL BENEFITS OF LNG VEHICLES

The main environmental benefit of using LNG instead of diesel fuel in heavy-duty vehicles is a reduction in tailpipe emissions of particulate matter (PM) and oxides of nitrogen (NOx). Emissions of CO, non-methane hydrocarbons (NMHC), and toxic air contaminants may also be affected, but diesel NMHC and CO emissions tend to be low in any case, and any further reductions would be difficult to quantify. The reduction in toxic air contaminants is also difficult to quantify, due to lack of data, and is largely accounted for by the reduction in PM-associated compounds such as polynuclear aromatic hydrocarbons (PAH). For purposes of this study, we have attempted to develop quantitative estimates only of the NOx and PM reductions.

Other environmental benefits of LNG use include the elimination of potential soil and water contamination by spilled or leaking fuel, reduced generation of hazardous waste contaminated with fuel, and a reduction in emissions contributing to global climate change. This reduction is due to the lower carbon content of LNG per unit of energy, which is about 1/3 less than that of diesel fuel. The resulting reduction in CO_2 emissions more than offsets the greenhouse impacts of the increase in methane emissions in the exhaust. Methane emissions in the LNG fuel cycle are sometimes high at present, but should be reduced to very low levels under the impact of EPA's emission regulations for gaseous fuels.

To estimate the reduction in NOx and PM emissions due to the use of LNG in heavy-duty vehicles, we used EPA's method based on a *conversion factor* (with units of BHP-hr per mile). While this method is subject to considerable uncertainty, no better method is available. Conversion factors were developed for heavy-duty line-haul trucks and for urban trucks, based on estimated fuel consumption. These were then multiplied by the emission levels for diesel and LNG trucks, estimated in g/HP-hr to give emissions in grams per mile. These estimates were then multiplied by the total number of trucks and the annual mileage per truck to give total emissions. Details of this process are discussed below.

3.1 Estimating Conversion Factors

Emission standards for heavy-duty diesel engines are defined in terms of mass of pollutant per unit of work produced by the engine. In the U.S., these emission standards are expressed in grams per brake horsepower-hour (g/BHP-hr). Expressing emission standards in this form is convenient, since it allows a single standard to apply to engines used in a wide range of heavy-duty vehicles. If emission standards for heavy-duty vehicles were expressed in grams per mile, as are standards for light-duty vehicles, it would be necessary to define many different standards to accommodate the wide range of heavy-duty vehicle sizes and weights.

Because the emission standards for heavy-duty engines are defined in g/BHP-hr, emission measurements on these engines are reported in the same units. As further discussed in Chapter Two, heavy-duty engine emissions are measured by operating the engine through a defined series of speed and load conditions on an engine dynamometer. Total emissions are divided by total work output to give the brake-specific emissions in g/BHP-hr.

Although convenient for engine certification, the expression of heavy-duty engine emissions in g/BHP-hr complicates estimation of emissions from vehicles in use. Data on vehicle traffic are generally expressed in vehicle-miles travelled, with no indication of the amount of work (BHP-hr) required to travel this distance. To estimate vehicle emissions in grams per mile, it is necessary to relate the distance travelled to the amount of work required to travel that distance. Presently, this relationship is established by means of a *conversion factor*, which is expressed in units of BHP-hr per mile. Multiplying the engine dynamometer emission result in g/BHP-hr by the conversion factor gives a result with units of grams per mile. The following equation illustrates the approach:

Emission factor = emission test data * conversion factor

or

gm/mi = (gm/bhp-hr) * (bhp-hr/mi)

The conversion factors presently used are based on relative fuel consumption as measured in the engine dynamometer test and on the road. Thus, an implicit assumption in the present methodology for estimated heavy-duty vehicle emissions is that *emissions are proportional to fuel consumption*. This assumption is not always accurate, but the data required to develop a more accurate model of heavy-duty vehicle emissions in real-world driving cycles are not available.

EPA's MOBILE5a_h emission model calculates emissions based on a set of fleet-average conversion factors, without regard to the differences in size, fuel consumption, and emissions between heavy-duty vehicle types. Since actual fleets are composed of differing sizes of vehicles, use of

Table 3: Conversion factors for heavy-duty vehicles.

Vehicle Class	Conversion Factor (bhp-hr/mi)	
	(Diesel)	(Gasoline)
L-HDT[1]	0.919	0.809
M-HDV[1]	2.245	1.558
H-HDV[1]	3.125	N/A
School Bus[1]	1.615	1.161
Transit Bus[2]	3.5	N/A
Average[3]	2.03	0.89

[1] Calculated using total vehicle sale fraction, diesel and gasoline sale fractions, and class-specific conversion factors from Machiele (1988).
[2] Comes to 4.3 bhp-hr/mi at 12 mph with MOBILE5 speed correction. 4.3 bhp-hr/mi is the CARB estimated conversion factor for transit buses (CARB, 1994)
[3] (EPA, 1998)

these average conversion factors would significantly distort the estimates. EF&EE therefore developed a set of conversion factors for individual vehicle classes, based on the data reported in the EPA's report on conversion factors (Machiele, 1988). These conversion factors are summarized in Table 3. Class-specific emission factors for HDVs can then be calculated by multiplying the HDDV or HDGV emission factors produced by MOBILE5a by the ratio of the class-specific conversion factor to the fleet average conversion factor. For instance, to calculate the emission factor for light-heavy duty diesel vehicles, one would multiply the MOBILE5a emission factor for heavy-duty diesel vehicles by 0.919 / 2.03.

For line-haul trucks, the average heavy-heavy duty vehicle conversion factor of 3.129 BHP-hr per mile was used. This value is equivalent to a fuel economy of 5.0 miles per gallon, with brake specific fuel consumption of 0.4 lb/BHP-hr. For urban trucks such as garbage trucks, we assumed a conversion factor of 4.3 g/BHP-hr, the same as for transit buses. This is reasonable, since both vehicle types experience heavy stop-start driving, resulting in high fuel consumption. This is consistent with fuel economy of 4.0 MPG, and brake-specific fuel consumption of 0.45 lb/BHP-hr.

3.2 Estimating Emissions in Grams per BHP-hr

Table 4: Estimated lifetime average emission levels of heavy-duty conventional and natural gas engines.

Engine Type	Estimated Emissions (g/BHP-hr)			
	NMOG	CO	NOx	PM
Diesel Engines				
M5a Diesel	1.03	4.78	3.60	NA
EF&EE Est. 1998 - 2003	0.30	1.00	3.10	.20
EF&EE Est. 2004 - 2010	0.20	1.00	1.70	.20
Natural Gas Engines				
EF&EE Est. 1996 - 2003	0.30	1.00	2.0	.02
EF&EE Est. 2004 - 2010	0.20	1.00	1.0	.02

MOBILE5a_h does not project emission factors for heavy-duty vehicles with natural gas engines, nor for vehicles with diesel engines meeting EPA's proposed 2004 diesel emission standards. In addition, MOBILE5a_h does not project PM emissions from diesel vehicles. A related model, PART5, does project PM emissions, but this model suffers from many deficiencies. The most significant of these deficiencies is that it does not account for PM emissions deterioration in use. Heavy-duty engines are projected to meet the emissions standards to which they have been certified, even in the absence of an I/M program, over their entire useful lives. This projection is highly unrealistic, since it is known that some heavy-duty engines develop injector and other problems that cause them to become gross emitters of particulate matter.

Estimated emission levels for each of several heavy-duty engine types are summarized in Table 4. The HC, CO, and NOx values labeled M5a diesel are those apparently used by MOBILE5 to calculate heavy-duty vehicle emissions from Tier I engines. These values were obtained by dividing the MOBILE5a emission factors for HDVs, at the MOBILE5 default speed of 19.6 MPH, by the average conversion factors documented in the Machiele report. This gives reasonable results - for instance, the diesel NOx value is 3.6 g/BHP-hr, which corresponds closely with the standard of 4.0 g/BHP-hr with 15% compliance margin.

The remaining emission values shown in Table 4 are EF&EE estimates, based on available heavy-duty engine emissions data and our estimate of the likely emissions performance of engines designed to meet EPA 1998 and 2004 standards. It should be noted that these estimates contain considerable uncertainty, especially as regards the CO and NMOG emissions. Present diesel and natural gas engines have NMOG and CO emissions well below the applicable emission standards, so that emission standards do not provide a reliable guide for estimating actual emissions. On the other hand, the NOx emissions are considered much less uncertain. For best fuel economy, diesel engines are usually calibrated so that their NOx emissions are as close to the standard as possible, while still retaining adequate compliance margin. Further, diesel NOx emissions do not usually deteriorate in use.

The estimated emission levels for natural gas engines are based on current certification data for these engines. A sampling of these data are shown in Table 5. Current natural gas engines are typically calibrated for NOx levels less than 2.0 g/BHP-hr, or less than half the NOx emissions from diesel engines. When diesel engine emissions are reduced to 2.0 g/BHP-hr in 2004, we expect natural gas engines to be calibrated for about half that level.

The particulate emission estimates shown in Table 4 are EF&EE's estimates, based on available emissions data. For diesel engines, we estimate that average PM emissions from vehicles in use will be at least twice the 0.10 g/BHP-hr standard. This is based on emissions data showing that malfunctioning engines can emit more than 5.0 g/BHP-hr, and our estimate that the incidence of such malfunctioning engines in the fleet is likely to be at least 2%. We believe these deterioration estimates to be highly conservative - i.e., actual PM emission levels are likely to be substantially worse, especially in the absence of an I/M program. Similar deterioration levels have been projected by the California Air Resources Board, based on a 1988 study that sought to quantify emissions deterioration in-use (Weaver and Klausmeier, 1988). PM emissions from natural gas vehicles are not expected to undergo similar deterioration. Unlike diesel engines, natural gas engines do not produce PM as part of the combustion process, so that degradation of the combustion system in use would not affect PM emissions.

Table 5: Emissions certification data for heavy duty natural gas and diesel engines.

Engine Model	Emissions (g/BHP-hr)			
	HC[1]	CO	NOx	PM
Diesel Engines				
Cummins B5.9	0.3	1.9	4.4	0.08
Cummins M11	0.2	0.9	4.8	0.06
DDC Series 50	0.1	2.0	4.8	0.10
Caterpillar 3306	0.5	0.8	5.0	0.09
Natural Gas Engines				
Cummins B5.9G	0.6	5.4	0.9	0.02
Cummins L10-260G	0.2	0.4	1.8	0.02
DDC Series 50G	0.7	2.5	2.7	0.05
Caterpillar 3306G	0.7	6.3	0.7	0.02

3.3 Estimating Total Emission Reductions Due to LNG Use

To estimate the total emission reduction that would result from increased market penetration by LNG trucks, we first calculated the total annual emissions per vehicle for a diesel and an LNG truck. Subtracting the LNG value from the diesel value gave the annual emission reduction per vehicle. This resulted in different values for the 1998 to 2003 and the 2004+ engines. The emission reduction per vehicle was then multiplied by the projected number of vehicles equipped with engines in each model year range.

Table 6: Emission reductions per vehicle due to LNG use.

	Line Haul Truck			**Urban Truck**		
	Diesel	**LNG**	**Reduction**	**Diesel**	**LNG**	**Reduction**
Model Years 1998-2003						
NOx emissions (g/mi)	9.70	6.26	3.44	13.33	8.60	4.73
NOx emissions (tons/yr)	1.28	0.83	0.45	0.59	0.38	0.21
PM emissions (g/mi)	0.626	0.063	0.563	0.860	0.086	0.774
PM emissions (tons/yr)	0.083	0.008	0.074	0.038	0.004	0.034
Model Years 2004+						
NOx emissions (g/mi)	6.26	3.13	3.13	8.6	4.30	4.30
NOx emissions (tons/yr)	0.83	0.41	0.41	0.38	0.19	0.19
PM emissions (g/mi)	0.626	0.063	0.563	0.860	0.086	0.774
PM emissions (tons/yr)	0.083	0.008	0.074	0.038	0.004	0.034

The reductions in NOx and PM emissions per vehicle are shown in Table 6. These were calculated by multiplying the estimated emissions in grams per BHP-hr by the appropriate emission conversion factor (BHP-hr per mile), giving a result in grams per mile. As mentioned earlier, this conversion is only approximately correct, since real-world driving cycles result in somewhat different operating conditions for engines in vehicles on the road than are experienced by engines on the test bench. The uncertainties in this calculation have been discussed elsewhere (Weaver and Anderson, 1996).

To calculate the total emission reductions due to LNG use, EF&EE multiplied the per-vehicle emission reductions shown in Table 6 by the projected number of LNG vehicles in 2000, 2005, and 2010. This calculation is shown in Table 7. For reasons to be discussed below, we used the vehicle population projection from Scenario 2 of the Zeus report, thus excluding from the calculation the incremental market penetration by LNG vehicles as a result of MERCs. The values shown in Table 7 are the projected reductions in annual NOx and PM emissions nationwide that would result from the increased use of LNG in heavy-duty trucks if the present LNG tax rate were made equivalent to the tax rate on CNG.

Table 7: Fleetwide emission reductions due to LNG Use.

	Line Haul Truck	**Urban Truck**	**Total**
Year 2000			
Total Vehicles Projected	1,000	1,000	2,000
MY 1998-2003	1,000	1,000	2,000
MY 2004+	0	0	0
NOx reduction (tons/yr)	455	208	663
PM Reduction (tons/yr)	74	34	109
Year 2005			
Total Vehicles Projected	2,750	5,250	8,000
MY 1998-2003	2,400	4,400	6,800
MY 2004+	350	850	1,200
NOx reduction (tons/yr)	1,236	1,078	2,314
PM Reduction (tons/yr)	205	179	384
Year 2010			
Total Vehicles Projected	5,250	10,250	15,500
MY 1998-2003	2,400	4,400	6,800
MY 2004+	2,850	5,850	8,700
NOx reduction (tons/yr)	2,270	2,025	4,295
PM Reduction (tons/yr)	391	349	740

It must be pointed out that the emission reductions calculated in Table 7 do *not* account for two potential important offsetting factors. The first of these is the effect of the emissions averaging, trading, and banking provisions of the heavy-duty engine emission regulations; while the second is the potential for MERC generation by LNG vehicles. To the extent that engine manufacturers take advantage of the former to produce higher-emitting diesel engines; or MERC purchasers take advantage of the latter to offset other required emission reductions, the net emission benefits will be greatly reduced. In either of these cases, the net effect would not be to reduce total emissions beyond the level that would already be achieved, but instead to make it possible to achieve the same level of emissions at lower overall cost. (It should be noted that these two alternatives are mutually exclusive - an emission reduction used by the engine manufacturer for averaging, trading, or banking cannot also be used to generate MERCs.)

4. TAX REVENUE IMPLICATIONS

Once the total emission reductions in each year were calculated, it was straightforward to calculate the total annual loss of fuel tax revenue to the Federal Government. This calculation is shown in Table 8. As these results show, the implications for federal tax revenue are relatively insignificant. About $5.9 million less in revenues would be collected in 2005 ranging up to $39.9 million less revenue in 2010. This growth in revenue losses is due to increasing penetration of LNG into the line-haul and urban truck markets.

Table 8: Tax revenue losses of reforming LNG tax policy.

	Line Haul Truck	Urban Truck	Total
Revenue Loss Per Vehicle	4195	1748	
Total Revenue Loss (million $)			
2000	4.2	1.7	5.9
2005	11.5	9.2	20.7
2010	22	17.9	39.9
2010	22	17.9	39.9

.

6. REFERENCES

Machiele, P.A. 1988. Technical Report: Heavy-duty Vehicle Emission Conversion Factors II: 1962-2000. EPA-AA-SDSB-89-01. US EPA. October, 1988.

Nimocks, Robert L., 1995. LNG Vehicle Markets and Infrastructure, report no. GRI-95/0423, prepared for the Gas Research Institute by Zeus Development Corporation, September, 1995.

Weaver, C.S., J.F. Anderson, and L.M. Chan, 1996. Conversion Factors for Heavy-Duty Vehicle Emissions Estimates, draft report to the Gas Research Institute, February , 1996.

Weaver, C.S. and R.F. Klausmeier, 1988. Heavy-Duty Diesel Vehicle Inspection and Maintenance Study. report by Radian Corporation to the California Air Resources Board, Sacramento, May 16, 1988.

APPENDIX A: STATE MOTOR FUEL TAXES

State	Gasoline	Diesel	Gasohol	CNG	LNG
Alabama	18	19	18	Permit	18
Alaska	8	8	None	None	None
Arizona	18	18	18	1	18
Arkansas	18.5	18.5	18.5	5	None
California	18	18	18	7	7
Colorado	22	20.5	None	20.5	20.5
Connecticut	32	18	31	18	None
Delaware	23	22	23	22	None
Dist. of Colum.	20	20	20	20	20
Florida	16.8	22.8	16.8	10.5	10.5
Georgia	10.5	10.5	10.5	10.5	10.5
Hawaii	15	15	15	11	11
Idaho	22	22	22	16.5	16.5
Illinois	19	21.5	19	19	19
Indiana	15	16	15	15	15
Iowa	20	22.5	19	16	16
Kansas	18	20	18	17	17
Kentucky	16.4	13.4	16.4	13.4	13.4
Louisiana	20	20	20	16	16
Maine	19	20	19	18	18
Maryland	23.5	24.25	23.5	23.5	23.5
Massachusetts	21	21	21	21	21
Michigan	15	15	15	None	None
Minnesota	20	20	20	20	20
Mississippi	18	18	18	18	18
Missouri	15	15	15	Decal	Decal
Montana	27	27.75	27	None	None
Nebraska	24.2	24.2	24.2	24.2	24.2
Nevada	23	27	23	23	23
New Hampshire	18	18	18	18	18
New Jersey	10.5	13.5	10.5	5.25	5.25
New Mexico	22	18	18	18	18
New York	22.51	24.51	22.51	22.51	22.51
North Carolina	21.95	21.95	21.95	21.95	21.95
North Dakota	18	18	18	18	18

State	Gasoline	Diesel	Gasohol	CNG	LNG
Ohio	22	22	12	None	22
Oklahoma	16	13	16	16	16
Oregon	24	24	24	24	24
Pennsylvania	22.35	22.35	22.35	12	12
Rhode Island	28	28	28	None	None
South Carolina	16	16	16	16	16
South Dakota	18	16	16	16	16
Tennessee	20	17	20	13	14
Texas	20	20	20	15	15
Utah	19	19	19	19	19
Vermont	15	16	15	None	None
Virginia	17.5	16	17.5	10	10
Washington	23	23	23	Decal	None
West Virginia	20.5	20.5	20.5	20.5	20.5
Wisconsin	23.1	23.1	23.1	23.1	23.1
Wyoming	9	9	9	None	None

Note: All fuels are taxed in cents per gallon except for CNG. Unless otherwise noted in the text, CNG is taxed in cents per 100 cubic feet.